

RECORDS OF CHANGES IN COLOR AMONG FISHES¹

BY CHARLES HASKINS TOWNSEND
Director of the New York Aquarium.

INTRODUCTION

(Figs. 310-321 incl., Plates 1-27 incl.)

Most of the tropical fishes on exhibition in the New York Aquarium have the capacity of making instantaneous changes in color according to their moods or to artificial excitements.

The men who feed and care for these fishes become acquainted with their different phases of coloration and detect them readily, while the casual visitor passes by unaware that the black and the white and the showily colored specimens in a certain tank are all of the same species and may all look alike a quarter of an hour later.

We did not realize at first the extent of the color changes going on in the tanks. When it became apparent that the tropical fishes indulged in many more changes than was supposed, observations were commenced with a view to recording all the changes practiced by each species.

Changes in color and pattern are caused by the contraction or expansion of color cells or chromatophores, which contain black, red, blue, yellow or other pigments. The movement of color granules in the color cells is controlled by the nervous system. The stimulus to color change is received through the eye; blind tropical fishes make no response to disturbance or to changes in environment, their color cells remaining inactive. Blind fishes from Mammoth Cave and blind salamanders from an artesian well in Texas, that were kept for months in the Aquarium, were pale and colorless, entirely lacking development of color cells.

The chameleon, the dolphin and the octopus are celebrated for their capacity to make changes in color, but fishes inhabiting

¹ In the preparation of these records the writer has drawn freely upon his three earlier papers on the same subject. The supply of such papers being exhausted, the present one will supplant them on the list of publications emanating from the Aquarium.

coral reefs possess color cells which enable them to surpass the performances of their eminent rivals. Their abilities in color change have been made known more recently because the public aquarium, where they can be observed more readily than in nature, is an institution of comparatively recent development. Tropical fishes being easily captured, transported and retained in captivity, the New York Aquarium exhibits many kinds from the coral reefs of Florida and Bermuda. Their colors are usually brilliant, whatever phases the various species may assume momentarily. Tropical birds and butterflies are no more showy than these inhabitants of the reefs. The changes in color which these fishes make in conformity with their moods or surroundings are, or at least can be, made instantaneously. A fish having little color may greatly alter its appearance by a mere change in the pattern of its markings.

The New York Zoological Society authorized the preparation of a series of paintings and photographs of tropical fishes, showing the various changes in color of which each species in the collections of the Aquarium is capable. Written descriptions of the various liveries assumed were prepared whenever the behavior of the fishes permitted but the work of photographing and painting the color changes was necessarily slower and more difficult. The camera and the artist are available when arranged for but the subject poses or performs to suit his own moods. Both the photographer and the artist endured tedious delays before the record for each species was completed. To avoid loss of time the artist kept outline drawings of two or three species in readiness so that he could turn promptly from one tank to another and apply the color without delay as the fishes under observation became active or quiescent.

The paintings which have been prepared showing from three to seven different phases according to the species may not even now after long continued observation be complete. Occasionally some fish furnishes a surprise by appearing in a guise not previously noticed. We have indeed found that with most species an additional color phase can be produced by stopping the flow of water until the fish becomes distressed, when it assumes colors or markings different from any of those displayed under normal conditions.

Such experimentation produces colorations that might be named distress phases. Similar appearances are assumed by fishes that are sick or injured. The display of markings or colors not previously recorded in the Aquarium we now regard as symptomatic of discomfort and the attendants take action accordingly. It is not easy to name the colorations appearing normally but experiment and observation have shown that certain well-known changes can be attributed to fright, to anger and to distress.

In our observations in recording normal changes in color and our experiments in producing others by artificial means, twenty-eight tropical species were closely watched. All of these were proved to have the capacity of making instantaneous changes from one set of colors or markings to another, while from three to seven guises each, according to the species, were clearly distinguished. It is possible that each kind is capable of additional transformations in its natural habitat, but as yet we know little of the habits of animals in the sea.

One is at first inclined to a feeling of surprise that the ability of fishes to assume half a dozen different costumes within the space of a few moments was not earlier understood, but many kinds of observations are scarcely possible in the natural state. It is necessary that certain details of animal behavior be studied under conditions involving captivity and the continuous observation of each individual, such as may be arranged in the large tanks of a well-equipped aquarium.

Reighard, who studied these fishes on the coral reefs of the Tortugas, concluded that their conspicuousness is without biological significance and that their agility affords them ample protection. It is true that the reef fish, like the chipmunk and the woodchuck, is seldom more than a few jumps from home. It finds security in proximity to the nooks and crannies of the reefs with their varied coral growths. The reef itself being a refuge, its conspicuousness is, according to Reighard, an expression of race tendency, independent of natural selection, the conditions of life permitting a suspension of selection so far as colors are concerned.

Longley, who also studied reef fishes at the Tortugas, rejects

the hypotheses of "warning and immunity coloration, signal and recognition marks and sexual selection" as applicable to reef fishes, but concludes that color and pattern have an "obliterative" function, their evolution having been guided by natural selection.

The study of gaudily hued fishes on coral reefs has as yet progressed little farther than the stage of reconnaissance. At the time when Reighard's investigations were made ('07), the great extent to which reef fishes alter their coloration was not known, their behavior in captivity not having been recorded.

We are not yet prepared to accept the conclusions arrived at by those who have confined their observations to the generally grayish reefs of the Tortugas, which lie near the margin of the tropic belt. After experiences on the coral reefs of more than forty islands in various parts of Polynesia, where the fishes are more gorgeous than in sub-tropical Atlantic waters, we are prepared to affirm that the abundance and variety of the invertebrate life alone is sufficient to give areas of the reefs such splendors in color that the most brilliant fish could soon find an environment to match without changing its own color in the least. Wallace,¹ in describing the harbor of Amboyna, says: "The bottom was absolutely hidden by a continuous series of corals, sponges, actiniae and other marine productions of magnificent dimensions, varied forms, and brilliant colors. In and out among them moved numbers of blue and red and yellow fishes, spotted and banded and striped in the most striking manner."

Hickson,² in referring to the marine fauna of Talisse in the Celebes, says: "This general account of a ramble on the reefs of Talisse is perhaps sufficient to indicate the immense variety of form and color of living corals that may be observed in many places, but it would take a separate volume to describe in detail all the different creatures, their marks and colors, their movements and their habits, which are to be found upon a hundred yards of such a coast." . . . "The brilliant colors of the reef fishes were first noted by Captain Cook and form one of the most striking features of the fauna of the tropical shores."

¹ Malay Archipelago.

² A naturalist in North Celebes

In Polynesia we found that the colors displayed by fishes were vastly more brilliant and varied than those of fishes in any part of the Atlantic.

The pictorial and other records made in the Aquarium show that a reef fish can no longer be regarded as a creature having some permanent life color but must be considered as having several colorations, any one of which may be assumed instantly. Provided with such records, the investigator in the field should be better equipped for his efforts toward interpreting the colors of fishes.

Fishes given to wandering among grayish reef heads, clumps of purple or yellow sea fans, settling on brownish rock surfaces or whitish sandy patches, must be benefited by the ability to adjust their colorations of body instantly to environments varying widely in color. That most of them, both in nature and in captivity, practise color change in moving about is beyond question. While mere immobility in a living animal lessens its visibility, its simulation to some extent of the background contributes also to the reducing of its conspicuousness.

Since our records have shown that reef fishes have from two to seven distinct normal color phases according to the species, attention should be called to the fact that colored plates of fishes as published in standard works on ichthyology show but one of several phases which the species is capable of assuming. Seen in some other phase the color plate might be useless for purposes of identification except in the hands of the expert acquainted with its structural characters. The color of a reef fish disappears when the specimen is preserved in spirits and a colored plate showing a single phase is obviously an imperfect color record. When similar records of color phases of many more species become available the specific names of a good many fishes will be relegated to the lists of synonymy.

The studies made in the New York Aquarium are, of course, based on the behavior of fishes in captivity, where the conditions of life are necessarily different from those encountered in nature. They are neither preyed upon nor compelled to seek prey. They

associate only with such other species as may be placed in the same tanks with them. Even when a large tank is fitted with rock work, patches of sandy bottom, purple and yellow sea-fans and clumps of sea weed, their surroundings at best are monotonous as compared with the diversified backgrounds to be found on their native coral reefs.

It is difficult under such conditions to determine the meanings of their color changes. Perhaps some of them have no serious meaning but are merely emotional like sudden flushing or pallor. The principal motive in changing color must be the impulse to conform with environment. If the fish rests among dark-toned rock-work, it is disposed to show its more banded or blotched phases. If it settles down upon a patch of grayish bottom it quickly assumes paler tones more in keeping with its change in position. Then there are the colors and markings displayed when under some excitement, as when food is thrown into the tanks, artificial light turned on, or the air-compressor started. Where several species are kept in a single tank there is more activity and a noticeable increase in the color changes of all of them.

If all of the many species under observation could be installed in tanks equipped with more varied backgrounds of rock-work, sandy bottom, sea weed, etc., their color changes, as they settle down in different situations, would doubtless be brought into play with even greater frequency. It is difficult to arrange surroundings that closely approximate nature and the work of providing reef-like environments has necessarily been slow. The gradual enlargement of exhibition tanks in the Aquarium is proceeding and each improvement of the kind affords opportunity for the placing of accessories which in the end will give our ocean rainbows greater inducements to show what they can do as they move from one position to another.

We know as yet little of the extent to which color change is practiced by fishes amid their natural surroundings on the reefs where observation is difficult. They may assume colors or markings useful in warning off enemies or revealing themselves to their own kind, which are not displayed during their sheltered lives in the tanks.

Certain feeding experiments conducted by Reighard at the Tortugas showed that the gray snapper (*Neomaenis griseus*) recognizes certain colors. Specimens of its favorite food fish, a species of *Atherina*, were artificially colored red, blue, yellow, etc. The snappers took them all readily, but when the red fishes had been rendered unpalatable by treatment with various substances, they soon learned to avoid them altogether, continuing to feed on those of other colors which had not been so treated. Such experiments indicate that perception of color by reef fishes exists.

So far we have been able to do little more than record the numerous changes they are capable of making in captivity, but these are striking and the tendency to make them is very strong. Certain color performances can be evoked at the will of the experimenter. It may be possible to produce others under the conditions of captivity, by introducing species of which they have an inherent fear. As the artificial conditions under which they live are apparently not conducive to breeding, it is possible that there are special color changes brought into play during their spawning periods.

We are loath to believe that the sudden flashing of a dozen regularly distributed white spots by the red parrot-fish is meaningless. While it may be so in the humdrum round of life in the tanks, in nature, surrounded by enemies, it may be a recognition signal to its mates. Some of our showy fishes feed at night as certain brightly colored reef fishes are known to do; there may be "obliterative coloration" in the ghostly whiteness sometimes assumed by the blue tang as the tanks become dark in the evening. In the wild state it may do this habitually at night and move quite away from the reefs to feed.

Observations on the color changes of fishes under normal conditions such as prevail on coral reefs will throw more light on this subject, but they are naturally more difficult to make and will require long-continued research. We are still far from satisfactory interpretations of the gaudy hues of most animals.

The common pig-fish (*Orthopristis chrysopterus*) has four liveries which it may put on and off within a few moments. One of these consists of seven or eight irregular, vertical, dark bands, not

unlike those of the northern tautog. When a number of heavily banded tautogs (*Tautoga onitis*) were placed in the tank with the pig-fish the latter wore its vertical bands habitually. It changed its habit of swimming about and usually rested on the bottom among the tautogs, from which a casual glance did not distinguish it, so nearly perfect was the mimicry.

A spade-fish (*Chaetodipterus faber*) was taken from its mates and placed in a tank with black angel fishes which have little power to change color, being habitually so dark as to be almost black. The spade-fish soon adopted the color of its new associates and remained nearly black for several weeks. When finally returned to the society of the spade-fishes, it took to the black and white bands which is their usual dress for every-day wear. The black coloration having become habitual while with the black angels, it evidently had to make some effort to maintain the customary livery of the spade-fishes and for several days there were frequent lapses into black. The experiment was repeated with another specimen with similar results. As both species inhabit the reefs and are at times associated, the behavior of the spade-fish in assuming the coloration of the black angel may be regarded as mimicry.

The Bermuda chub (*Kyphosus sectatrix*), a fish having little color, changes quickly from its striped to its spotted phase and back again in play, as the fishes chase one another from place to place. At times the change is made slowly enough to show a combination of both phases, as may be seen in the photograph on page 343. The photographer was unusually fortunate in this case, exploding his flash powder at the critical instant. Work of this kind has generally been done at night by flashlight, as the building is too dark for instantaneous photography in the daytime.

When the flow of water is stopped and the air-pump started, all of the chubs in the tank at once assume the spotted phase, which is retained an hour or more until the flow of water is restored. The white spots are unusually sharp and distinct at such times, over the entire body except on the head, but all the fins remain very dark. A pure white band develops across the top of the head, with longitudinal white bands along the jaws. All the fishes keep

swimming actively and are excited over the fountain of white bubbles escaping from the air tube at the bottom of the tank.

Two small red-mouthed grunts (*Haemulon flavolineatum*) were placed in a small photographic aquarium built so narrow that they could neither get out of focus nor turn around. They were carried out of doors where bright daylight permitted quick work and were photographed in the midst of their color attempts at concealment. Badly frightened, they turned very dark and remained so, the specimen on the right as shown in the photograph on page 344 turning light and showing two longitudinal black lines only after considerable prodding with a stick. The customary coloration of this species when undisturbed is a pale golden yellow with diagonal silvery stripes, as shown (lower) on page 344. When alarmed, the whole school bunches together at the bottom, all immediately assuming a dark-mottled appearance, the ground color becoming so dark that the fish is completely changed. The dark blotches disappear when the disturbance ceases, the specimens one after another assuming their ordinary coloration.

The fact that some fishes are nocturnal in their feeding habits must not be overlooked. In the dark their obscurer colorations may serve to make them indistinguishable.

The power of camouflage among fishes and some other animals must have its uses or it would not have been developed. It is well known that conspicuously marked or colored mammals, birds, reptiles and insects lacking the capacity to make such changes in appearance, often render themselves inconspicuous when at rest, by seeking positions where their colors or broken markings merge with their surroundings. Readily visible on close view, the sharply marked animal may practically disappear at longer range, or if nocturnal in habit, be more indistinguishable in the dark than if uniformly colored.

It should not be assumed that the different aspects caught by the artist are all that the species under observation can present. The responsiveness of the color cells to the transient excitements of the fish are such that no two artists portray well known guises absolutely alike. No two photographs are quite the same even if

the fish in front of the camera has not moved. While certain general changes in appearance are identifiable by any one, it soon becomes evident that intensity of color or pattern depend upon the individual fish under observation. In the coney, the graysby, the red hind, the hog-fish and most of the groupers, we are confronted with such activity of the chromatophores that no two of a species are ever completely identical in appearance.

Among the more active species, the duration of the colors assumed from time to time is uncertain until the fish comes to rest, when it may be greatly prolonged.

It is evident that the amazingly varied appearances possible to tropical fishes, so readily observable under the conditions of captivity, have not been fully appreciated by those who have studied them at longer range. No other creatures can compare with the fishes in this respect. All impulses, reactions, movements, find instant reflection in the kaleidoscopic color cells.

The visitor at the Aquarium need not expect to see in a short time many of the colorations of which a species is capable. The records and pictures presented here are the result of long-continued observation by the recorder and the artist, both by day and in the dusk of evening. Some of the recorded changes in appearance were brought about only by experimentation.

The writer is indebted to Hashime Murayama, Herbert B. Tschudy, Olive Earle and Charles R. Knight for painstaking efforts in portraying the behavior of their capricious subjects. Mr. L. L. Mowbray, curator of the Bermuda Aquarium, demonstrated for me the relationship between the yellow-finned grouper and the so-called "princess rockfish." Each has its own colorations, the differences being due to depth of habitat. Both are *Mycteroperca venenosa*.

SPECIES AS ILLUSTRATED BY COLORED PLATES AND PHOTOGRAPHS

Shark-suckers habitually cling to the bodies of sharks by means of an air disk on top of the head. One of these (*Echeneis naucrates*) has for many years been exhibited at the New York Aquarium, where one or more individuals may be seen clinging to a shark or swimming close beside it. Three of its phases of coloration are shown in plate 1.

The shark-sucker often changes from black with white stripes to gray or even jet black. While clinging to or swimming close beside the shark, the darker costumes are usually worn. When kept in a tank by itself it often clings to the glass front and becomes uniformly gray. It may even assume a position on the bottom of the tank, turning over and applying the sucking disk on the top of its head to the concrete floor, so strong is the inclination to make fast to something. The color changes practiced by this fish are usually made instantaneously. Those shown here are the ones usually displayed, but frequently when the upper surface and the black stripe along the side remain black the fish may turn entirely white beneath.

It inhabits warm seas in association with sharks, porpoises, whales and turtles.

A hardy fish that lives many years in captivity is the Spade-fish (*Chaetodipterus faber*). Its usual appearance is silvery with five or six heavy cross-bands of black, but at times some of the specimens become either entirely white or dull black. These changes are generally of brief duration. If frightened all the specimens in the tank instantly assume their black cross-bands. There is a decided tendency in this species to become dark in the evening. The black bands have a tendency to become obscure in very large specimens. Having perhaps ceased to be concerned about enemies, the large fishes may have less inclination toward changes in color.

The Spade-fish is a tropical species, found from Brazil to our South Atlantic coast, sometimes extending its summer range to the latitude of Massachusetts. We have taken late summer stragglers in New York Bay. It is reported to feed on the "Portuguese man-of-war" (*Physalia*) and that fishermen at Trinidad capture it with that jelly fish as bait.

Eight phases of coloration are sometimes observed in a tank containing specimens of the Nassau Grouper (*Epinephelus striatus*). In one the fish is uniformly dark; in another creamy white. In a third it is dark above, with white underparts. In a fourth the upper part of the body is sharply banded, the lower pure white. A fifth phase shows dark bands, the whole fish taking on a light

brown coloration. While in a sixth the fish is pale, with all dark markings tending to disappear. The seventh phase shows a light colored fish with the whole body sharply banded and mottled with black. (See photograph p. 345.) This is instantly assumed by all specimens when they are frightened and seek hiding places among the rock-work. The banded phase shown here is no more the normal appearance of the fish than the uniformly dark, the uniformly white, or any other phase. Singularly enough, no two photographs of this banded phase are quite alike, the extent of the markings being dependent apparently upon the degree of disturbance to which the fish has been subjected.

The artist has not shown a rarer guise when the body is dusky above, white below, with a median black band from head to tail. This is an important food fish of Bermuda, Florida and the West Indies. Specimens have been taken weighing as much as fifty pounds.

The Red Grouper (*Epinephelus morio*) assumes nearly as many colorations in the course of the day as the Nassau Grouper. One of these is dusky black; another brownish with blotches of white; a third, still lighter, has broad brownish bands. The others show various shades of fawn color without markings on the body.

The red grouper is an important market fish, common along our South Atlantic and Gulf coasts and in the West Indies. Large specimens often exceed twenty pounds in weight.

The Black Grouper (*Mycteroperca bonaci*) has no showy colors but frequently makes changes varying from white to black. In the first there may at times be black edging on dorsal, anal and caudal fins. An intermediate rather light phase shows four vertical rows of dark brown rectangular blotches, the lower half of the body being closely covered with brownish dots. In a third change, both dots and blotches slowly disappear as the fish becomes practically black. Between these rather common colorations there are variations which the artist does not portray. The photograph shows one of these phases.

Distribution—From Florida and Bermuda to Brazil.

The usual appearance of the Yellow-finned Grouper (*Myctero-*

perca venenosa) with the body sharply mottled is shown at the top of plate 6. When the fish turns white as it sometimes does, all color disappears except the black border of the soft dorsal and caudal fins. Even the minute red dots which ordinarily cover the whole body are lost.

In the phase shown below, the markings become dim. They are often lost entirely in a deep brown coloration which the artist has not shown. Specimens observed in March, 1929, at the Bermuda Aquarium displayed two other phases not shown on plate 6: one pale with dark blotches on back, while another had the upper half of body crimson, with blotches showing faintly, the lower surface being very pale crimson.

An important food fish ranging from Florida and Bermuda southward.

The colored plate of the dainty Princess Rockfish (*Mycteroperca venenosa**) needs little explanation. The artist has shown its three principal guises perfectly: white, with the evenly distributed black spots reduced to the minimum; second with the always present black spots at their maximum intensity; and third a similar phase with the underparts crimson. This fish is so rarely brought to the Aquarium that it was never placed in the photographer's portable tank. What markings it might display if subjected to that alarming process are still unknown. The three colorations shown here are all assumed as the fish moves about unmolested. A fourth phase is shown in the photograph p. 346.

Distribution—Florida and Cuba.

The visitor looking at the 200-pound Giant Grouper (*Promicrops guttatus*) and interested chiefly in its large size may occasionally have a chance to marvel at something else than its bulk. The usually dark fish may suddenly shift its position and appear as a nearly white fish with heavy black blotches from head to tail. It may change its position again and assume a creamy-white coloration while the dark blotches or bands slowly fade out. The artist has not shown this fish in a fourth phase, in which it becomes uni-

* Recent observation of many specimens in the Bermuda Aquarium (March 1929) shows this fish to be a shallow water variety of *Mycteroperca venenosa*.

formly dusky black. The behavior of the two giant groupers, which are kept in separate tanks, is interesting: one has lived ten years in the Aquarium without ever disturbing any of the dozen kinds of smaller fishes living with it, while the other has promptly swallowed all fishes placed in its tank, one of these being a young brown shark two and a half feet long. The mouth of the giant grouper measures ten inches across.

Range in the Atlantic—From Florida and Bermuda to Brazil.

The Coney (*Bodianus fulvus*). Groups of this species as received at various times in the past have varied more or less from those collected in 1927, the principal colorations of which the artist has shown here. The color phases described by the writer in 1908¹ do not correspond in details with those of coneys now in the Aquarium. Few fishes are capable of as many intergradations. Between the two phases showing solid color—the red, at bottom and the dark, at upper right of plate 9—there are three other distinct phases that are assumed naturally. Persistent annoyance by the observer's assistant such as driving the fishes from one hiding place to another will also produce them in varying degrees of intensity.

Individual coneys indulging in frequent changes when first placed in the tanks may later take to a single coloration and maintain it habitually with but little temporary alteration. Such fishes are inclined to select a comfortable situation among the rock-work, sometimes head downward in a crevice and may be found there day after day. Others may be more active, some of them fighting until their jaws are lacerated and unsightly. Hostile coneys hang bulldog-like to each other's jaws, and after exhausting struggles return to fight again. Their colors when fighting are different from those displayed at other times and the artist did not feel equal to the task of recording them.

In the afternoon of September 15, 1927, we observed that all of the coneys in the tank had temporarily assumed the pale coloration of the specimen shown at the top of plate 9. At another time a coney that had maintained the dark red coloration persistently was placed in a separate tank for observation when it

¹ 13th Ann. Rept. N. Y. Z. S.

assumed and retained the pale phase. The coney that has been described as *Bodianus fulvus* and its two subspecies *ruber* and *punctatus* are all color phases of one species, as may be seen in plate 9. An additional coloration observed in the Bermuda Aquarium in March, 1929, is like that of figure at top of plate 9, but with the back, from snout to end of soft dorsal, bright vermilion.

Range—Florida and Bermuda southward to Brazil.

Graysby (*Petrometopon cruentatus*). The various colorations and markings assumed by this fish presented serious difficulties to the painter. He has shown only the four phases which are most distinct: the palest with four or five evenly placed black spots below dorsal, the darkest with similar spots of white instead of black, the red with pale blotches and the dark with white blotches. While all of these may often be seen as shown on plate 10, they are varied at times until they intergrade. Occasionally the black dots flash out in both red and the dark blotched phases. The white blotchings at times unite into vertical bands on the body and horizontal bands on the head. The fish can turn so dark that the numerous brownish dots, more or less persistent in the usual colorations, practically disappear.

Range—Florida and Bermuda to Brazil.

Red Hind (*Epinephelus maculosus*). This fish has three principal color phases—red, banded and pale—all of which may be seen at any time in a tank containing numerous specimens. The different colorations appear as the fishes move about, come to rest on the bottom or seek shelter among the rocks. The numerous red dots covering all of the body except the fins persist at all times with little change. In the red phase the ground color of the body reddens and all fins except the pectoral and spinous dorsal become very dark. The ground color is less red when the fish assumes the heavy dark bands, while the dark fins become lighter. (See photograph, page 347.) In the pale phase the red ground color and the dark cross bands disappear, while the fins lose nearly all color except on their margins. Between these principal colorations there are several gradations.

The color changes of the Rock Hind (*Epinephelus adscensionis*)

come quickly and are hard to follow. The artist has not caught them in their most contrasting aspects. Like the red hind it usually stays among the rock-work of the tank. Its frequent changes in position are always accompanied with changes in color and pattern. The red dots which cover the body and most of the fins remain unchanged at all times. Numerous small white spots on the body may instantly give way to large dark blotches, or the fish may assume wide pale cross bands.

The rock hind is an excellent food fish, reaching a length of about eighteen inches. It is found in southern Florida and throughout the West Indies.

Blue-striped Grunt (*Haemulon sciurus*). This species when moving about undisturbed is of uniformly pale golden color, with numerous longitudinal stripes of blue. Under temporary excitement, as when being fed, the dorsal and caudal fins turn black. If alarmed, a few heavy cross bands appear. These may be on the upper part of the body, as shown on plate 13, or lower as in the photograph, page 348.

A valuable food fish ranging from Bermuda and Florida southward to Brazil.

The Gray Grunt (*Haemulon plumieri*) is usually gray, as shown in the lower figures of plate 14. At times it becomes dark brown. If alarmed it attempts to hide, when the body becomes mottled gray and brown except beneath.

Most of the species of grunts have the habit of pushing against each other with their snouts in play, when their red mouths are opened widely.

This is one of the most important food fishes among the numerous species of grunts found along our south Atlantic coast. It does not usually exceed a foot in length.

The Grass Porgy (*Calamus arctifrons*) varies its appearance rapidly when under excitement, the changes ranging from a pale unmarked phase to one not unlike that of the sheepshead, with about the same number of heavy black cross bands. Between these extremes we often see a fish with the cross bands broken apart into evenly placed dark blotches, usually four to the row

(see photograph on page 348), or a still darker coloration in which the bands and blotches tend to fuse together. When placed in the small photographic tank the frightened fish often becomes darker than any shown on plate 15 with minute white dots scattered over most of the body.

Range—Coasts of south Atlantic and Gulf states.

The Glass Eye (*Priacanthus arenatus*) has color cells well stored with vermilion pigments but the rich color is under perfect control and may be restrained to produce mottled or banded effects or actually reduced until the fish is almost white. When the brilliant color is displayed to its greatest extent even the white of the large and conspicuous eye is suffused. All of the colorations shown here may occasionally be seen among the fishes at one time.

This species is probably nocturnal in its habits as its very large eyes seem to indicate. Specimens in captivity are disposed to seek the darker or shaded parts of the tank during the day.

The Glass Eye belongs to the West Indies region, occasionally wandering northward, possibly with the aid of the Gulf Stream, to Massachusetts in summer. The specimens in the Aquarium are from Florida. It is a food fish reaching a length of a little more than a foot.

The Sergeant Major (*Abudefduf saxatilis*) wears five vertical black bands, the body color usually being yellow, but this often gives way to bright silvery between the black bands. Both of the lighter colors are lost at times in a general darkening of head, body and fins. A very dark phase is often assumed, when the bands disappear entirely and the fish is uniformly black. The artist failed to show this coloration.

This fish inhabits both coasts of tropical America. Its range in the Atlantic is from Florida and Bermuda to South America. It is usually to be seen in schools in the vicinity of wharves.

Brown Parrot-fish (*Pseudoscarus guacamia*). This is the largest and hardest of the parrot fishes. The paler and the more colorful phases are shown in the upper figures of plate 18. In both of these the green color of the large scales persists with varying intensity, but disappears in the heavily blotched phase shown

below. The fish when hiding in the rock-work of the tank may assume a still darker coloration than that seen in the lower figure and if frightened is certain to do so. All the changes are made quickly as the fishes move about the tank. We have shot specimens two feet in length with the rifle, on the shallow reefs at Swan Island in the Caribbean Sea, that had the reddish brown color which gives this species its name. This coloration is seldom seen in the smaller specimens in the Aquarium. The brown parrot-fish is found from Bermuda and southern Florida to South America.

The Red Parrot-fish (*Sparisoma abildgaardii*) is one of the most interesting among the species subject to sudden changes in color. In the brightest phase (figure at upper right in plate 19) there is a nearly uniform red on the under surface and lower fins. The sides and upper surface turn dark. In the first, third and fifth rows of scales, each third, fourth or fifth scale in the row turns pure white, giving the fish about sixteen regularly distributed white spots, while the dorsal and caudal fins become pink. In another change the head, dorsal and tail become pale, while white spots appear on the second row of scales and tend to disappear on the fifth. In this phase the head may become yellowish (figure at lower left).

Between these colorations are two variations, pale with little color (upper left) and half-spotted (lower right).

In still another phase there is a pure white band along the side from head to tail which was not observed by the artist. The palest and the darkest phases are shown in the photographs on page 349. The Red Parrot is found from Florida and Bermuda southward to Brazil.

The color changes of the Blue Parrot-fish (*Scarus caeruleus*) are so varied that they range from a greenish blue with the upper half of the body quite dark, to a paleness in which the coloration is more suggestive of light green than blue. Between these the ever changing fishes display shades and patterns difficult to describe. At times the darkness of the upper parts is broken by three or four light cross-bands, or the fish may become a uniform greenish blue. In the reproduction of plate 20 the generally bluish coloration of this fish was unfortunately lost in a greenish tinge.

Range—West Indies northward to Bermuda and Florida.

Two striking phases of coloration are assumed by the Blue Tang (*Teuthis caeruleus*), one a dark blue, the other a creamy white. The blue phase is the one usually seen, since it is assumed whenever the fish is in the least disturbed by visitors passing the tank and this lasts all day long. The other phase is seldom seen until evening when the fish may settle down toward the white sand bottom and take on a ghostly whiteness, the blue color remaining only as a narrow border on the fins. Any disturbance instantly brings back the blue color. Sometimes under temporary excitement the fish displays three or four vertical pale bands across the upper half of the body, as shown in the middle figure of plate 21. The intensely blue coloration which the blue tang frequently assumes was not observed by the artist when this species was painted.

Range—Florida and Bermuda to Brazil.

The Surgeon-Fish (*Teuthis hepatus*) gets its name from the sharp-edged, erectile spines which occupy sockets on each side of the tail. With these innocent-looking lancets turned out at sharp angles it can inflict serious wounds. We have had a finger cut to the bone as neatly as if slit with a knife. The fish changes color with great frequency; from light brown with numerous cross bands it turns a dark brown with cross bands scarcely showing, or becomes quite pale except for momentary tinges of pale greenish blue.

This fish lives well in captivity. Although largely herbivorous, the Aquarium has kept specimens as long as five years on a fish and clam diet varied occasionally with seaweed. It is used for food and reaches a length of about a foot. Its distribution is from Florida and Bermuda southward to Brazil.

We are scarcely prepared to discover changeable color cells in that hard-shelled tortoise of the sea, the trunk-fish, so different from ordinary scaled fishes, but it has the capacity to change its appearance, although its chromatophores contain no pigments producing showy colors. The buffalo trunk-fish (*Lactophrys trigonus*) changes from black to white or to a mottled condition varied with minute white spots. (See also photograph on page 350.) In this species all changes in color are made slowly.

Range—West Indies, Florida and Bermuda, occasionally northward to Massachusetts.

The Cowfish (*Lactophrys tricornis*), like the other members of the trunkfish family, is encased in a hard tortoise-like shell, absolutely inflexible but perforated where the lips, eyes, fins and tail protrude. Its name is naturally suggested by the pair of horn-like spines on the head. It has a strong tendency to masquerade in different guises, its magical color cells responding to the impulse for a change in appearance. Pure white perhaps at first, it may later be found in three darker costumes, each decorated with reticulations of blue.

The cowfish is common throughout the West Indies and is found northward as far as the Carolinas. It is rather slow in movement, the three-angled body being propelled by the dorsal and anal fins. The tail is ordinarily used as a rudder but is brought into rapid play when the fish is disturbed. Although it will live an hour or two out of water it does not survive in captivity longer than two years.

The picture of the Queen-Trigger-fish (*Balistes vetula*) shows four color phases of this marine chameleon. The brightest and the lightest shown above are both normal: the dull color of the fish shown in the middle at the left is assumed when resting and also in case of fright; the fourth phase, at the bottom, indicates distress when the flow of water in the tank is cut off.

Range—West Indies, occasionally northward to Massachusetts.

File-fishes newly arrived at the Aquarium are always dark colored—usually more uniformly dark than the one shown in the center of plate 26. The pale phases seldom appear until several days later when they are assumed and sometimes retained indefinitely. Body and fins alike may take on a milky whiteness. The color changes are always made slowly, except when one of the white fishes is captured in a dip net. It then changes quickly, first to a mottled condition and then to the very dark phase. The file-fish (*Monacanthus hispidus*) is of small size, never exceeding ten inches in length. It has a wide distribution, being found from Massachusetts southward to Brazil. It is often taken in lower New York Bay in summer.

A fish that plays the harlequin so frequently that it can be depended upon to perform color tricks "before company" at almost any time is the hog-fish (*Lachnolaimus maximus*). When moving about the tank it has a pale brownish coloration, which gives place instantly to a heavily mottled phase when it comes to rest. (See photograph (top) page 351.) The pale coloration is at times varied to a marked degree when the entire front of the head becomes bright reddish-brown, while more or less blue appears on the tail. Any disturbance of the fish in the pale condition results immediately in the mottled guise. The hog-fish is lively and its color changes are all the more noticeable by reason of its size, large specimens weighing as much as twenty pounds. Its distribution is from Florida and Bermuda southward throughout the West Indies.

FIGURES FROM PHOTOGRAPHS

- Fig. 310 Bermuda Chub (*Kyphosus sectatrix*).
 " 311 { Red-mouthed Grunt (*Haemulon flavolineatum*)
 { Red-mouthed Grunt (*Haemulon flavolineatum*)
 " 312 Nassau Grouper (*Epinephelus striatus*)
 " 313 Black Grouper (*Mycteroperca bonaci*)
 " 314 Yellow-finned Grouper (*Mycteroperca venenosa*)
 " 315 Coney (*Bodianus fulvus*)
 " 316 Red Hind (*Epinephelus maculosus*)
 " 317 Blue-striped Grunt (*Haemulon sciurus*)
 " 318 Grass Porgy (*Calamus arctifrons*)
 " 319 { Red Parrot-fish (*Sparisoma abildgaardi*)
 { Red Parrot-fish (*Sparisoma abildgaardi*)
 " 320 Buffalo Trunk-fish (*Lactophrys trigonus*)
 " 321 { Hog Fish (*Lachnolaimus maximus*)
 { Hog Fish (*Lachnolaimus maximus*)

COLOR PLATES

- Plate 1 Shark-sucker Olive Earle
 " 2 Spade Fish Hashime Murayama
 " 3 Nassau Grouper Herbert B. Tschudy
 " 4 Red Grouper Herbert B. Tschudy
 " 5 Black Grouper Olive Earle
 " 6 Yellow-finned Grouper Herbert B. Tschudy
 " 7 Yellow-finned Grouper (var.) Herbert B. Tschudy
 " 8 Giant Grouper Hashime Murayama
 " 9 Coney Olive Earle
 " 10 Craysby Herbert B. Tschudy
 " 11 Red Hind Olive Earle
 " 12 Rock Hind Olive Earle
 " 13 Blue-striped Grunt Olive Earle
 " 14 Gray Grunt Hashime Murayama
 " 15 Grass Porgy Hashime Murayama
 " 16 Glass Eye Hashime Murayama
 " 17 Sergeant Major Hashime Murayama
 " 18 Brown Parrot-fish Olive Earle
 " 19 Red Parrot-fish Hashime Murayama
 " 20 Blue Parrot-fish Hashime Murayama
 " 21 Blue Tang Hashime Murayama
 " 22 Surgeon Fish Herbert B. Tschudy
 " 23 Buffalo Trunk-fish Hashime Murayama
 " 24 Cowfish Hashime Murayama
 " 25 Queen Trigger-fish Charles R. Knight
 " 26 File-fish Hashime Murayama
 " 27 Hog Fish Herbert B. Tschudy



Fig. 310. Bermuda Chub (*Kyphosus sectatrix*). Striped and spotted phases.

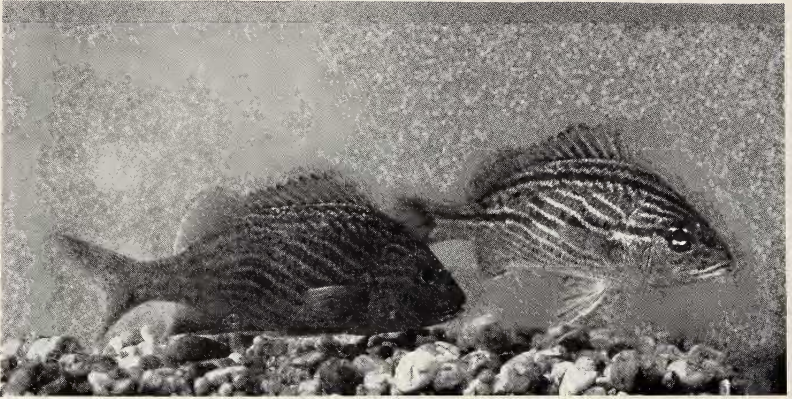


Fig. 311. Red-mouthed Grunt (*Haemulon flavolineatum*). Striped and dark phases.



Fig. 311. Red-mouthed Grunt (*Haemulon flavolineatum*). Usual coloration.



Fig. 312. Nassau Grouper (*Epinephelus striatus*). Heavily banded phase.

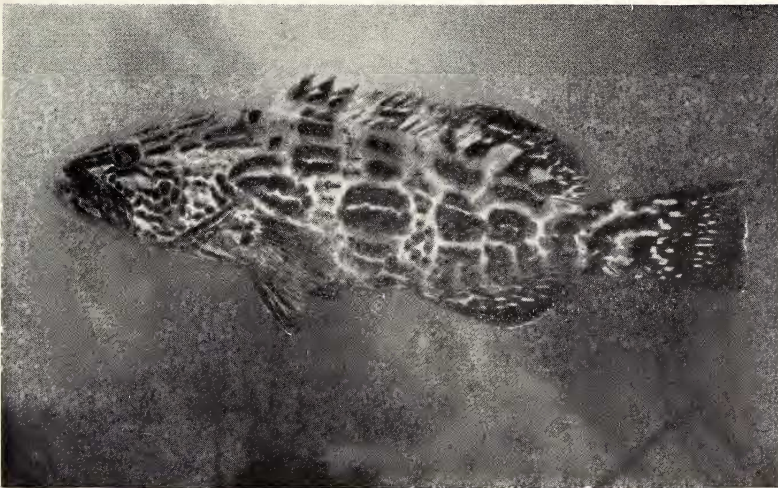


Fig. 313. Black Grouper (*Mycteroperca bonaci*). Heavily blotched phase.



Fig. 314. Yellow-finned Grouper (*Mycteroperca venenosa*). Shallow water variety known as "Princess Rockfish."

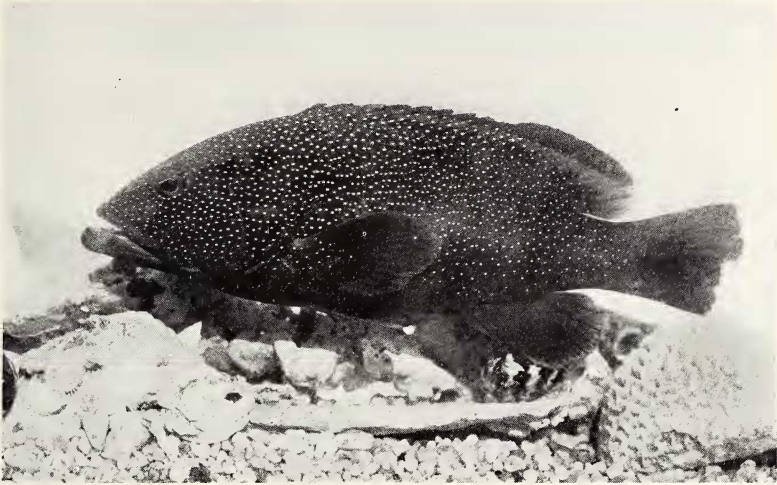


Fig. 315. Coney (*Bodianus fulvus*). Darkest phase.

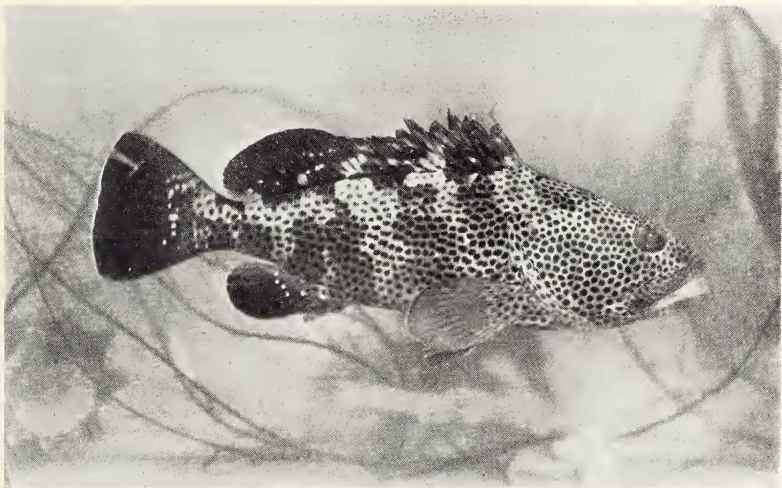


Fig. 316. Red hind (*Epinephelus maculosus*). Heavily-blotched phase.

The blotched appearance as shown in the photograph is often seen when the fish is at rest. It may be produced among all the specimens instantly by frightening them.

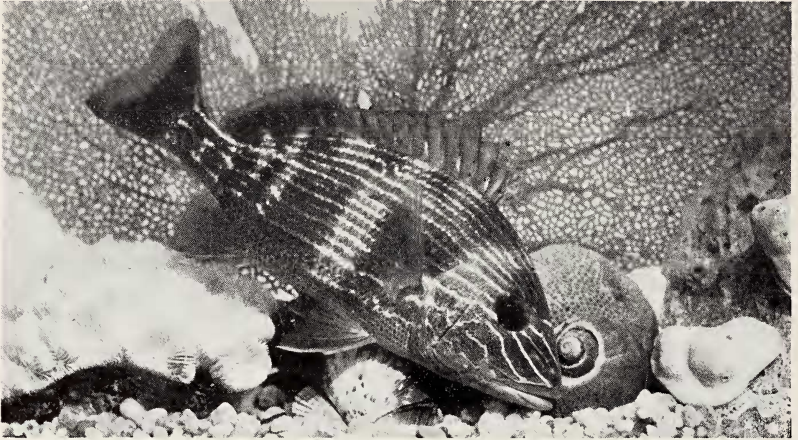


Fig. 317. Blue-striped Grunt (*Haemulon sciurus*). Blotched phase.

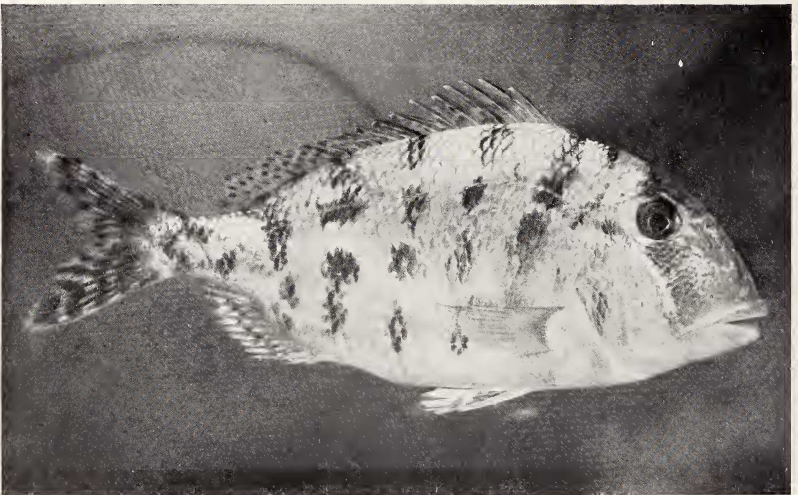


Fig. 318. Grass Porgy (*Calamus arcifrons*). Light spotted phase.

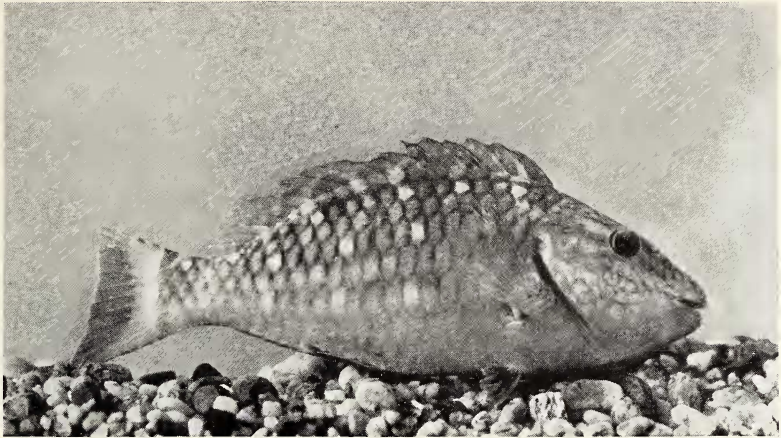


Fig. 319. Red Parrot-fish (*Sparisoma abildgaardii*). Light spotted phase.



Fig. 319 Red Parrot-fish (*Sparisoma abildgaardii*). Dark spotted phase.

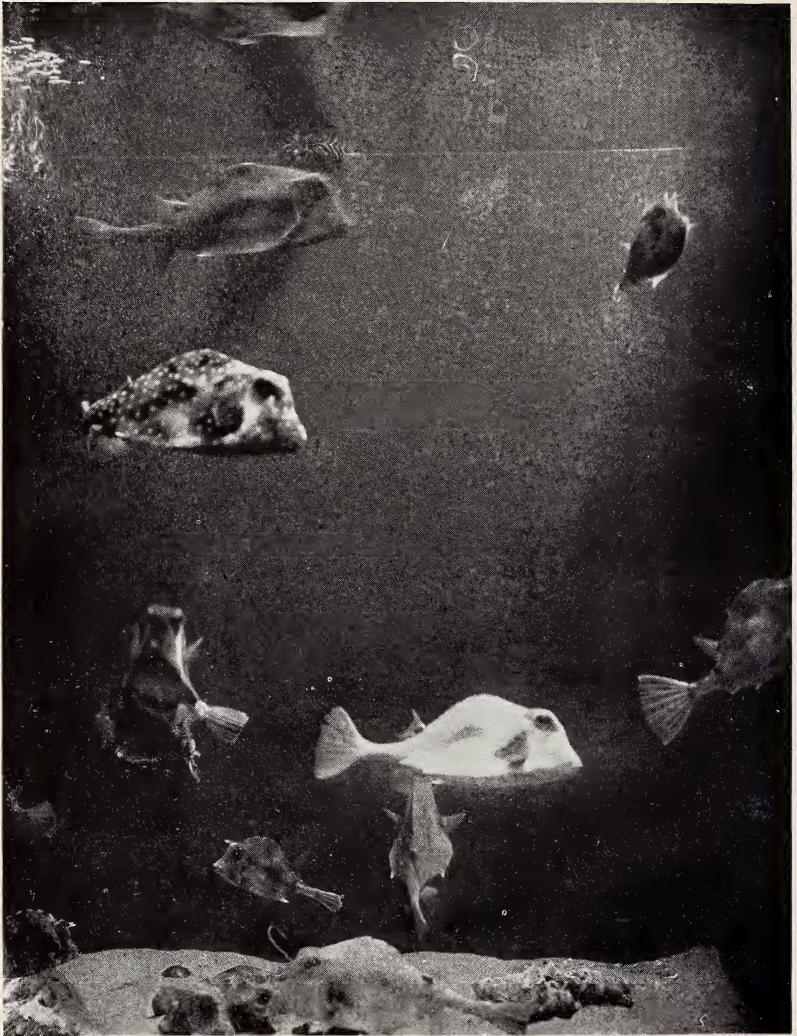


Fig. 320. Buffalo Trunk-fish (*Lactophrys trigonus*). Three phases.

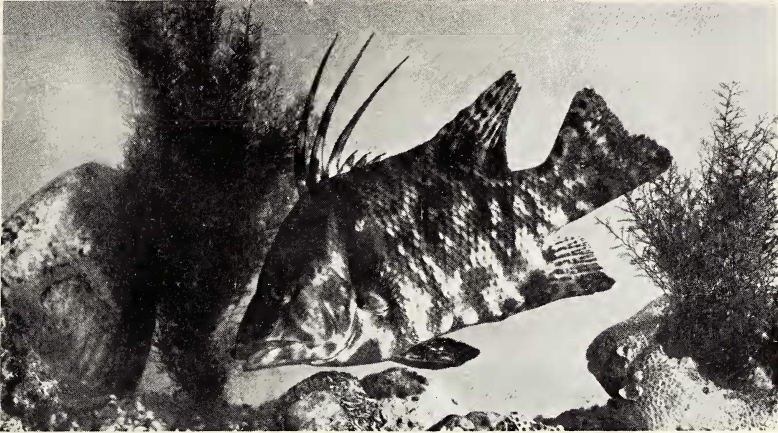


Fig. 321. Hog Fish (*Lachnolaimus maximus*). Heavily blotched phase.

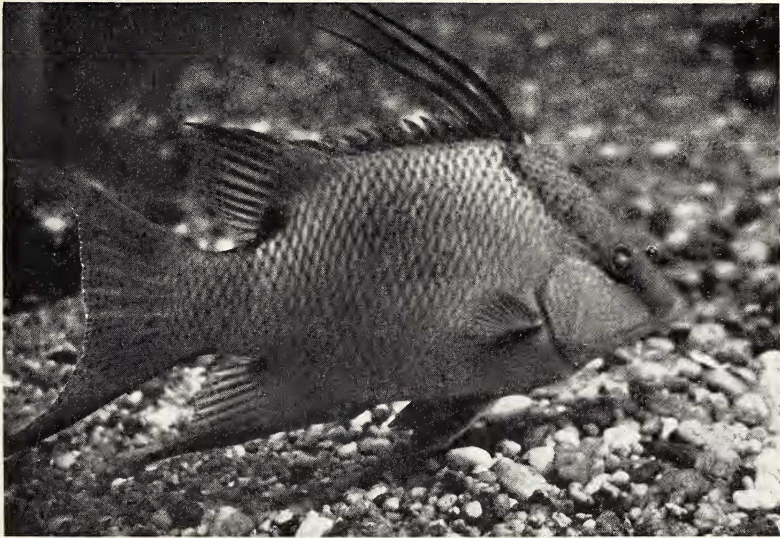


Fig. 321. Hog Fish (*Lachnolaimus maximus*). Red-fronted phase.



Plate 1. Shark-Sucker (*Echeneis naucrates*). Three color changes.



Plate 2. Spade-fish (*Chaetodipterus faber*). Three color changes.



Plate 3. Nassau Grouper (*Epinephelus striatus*). Seven color changes.

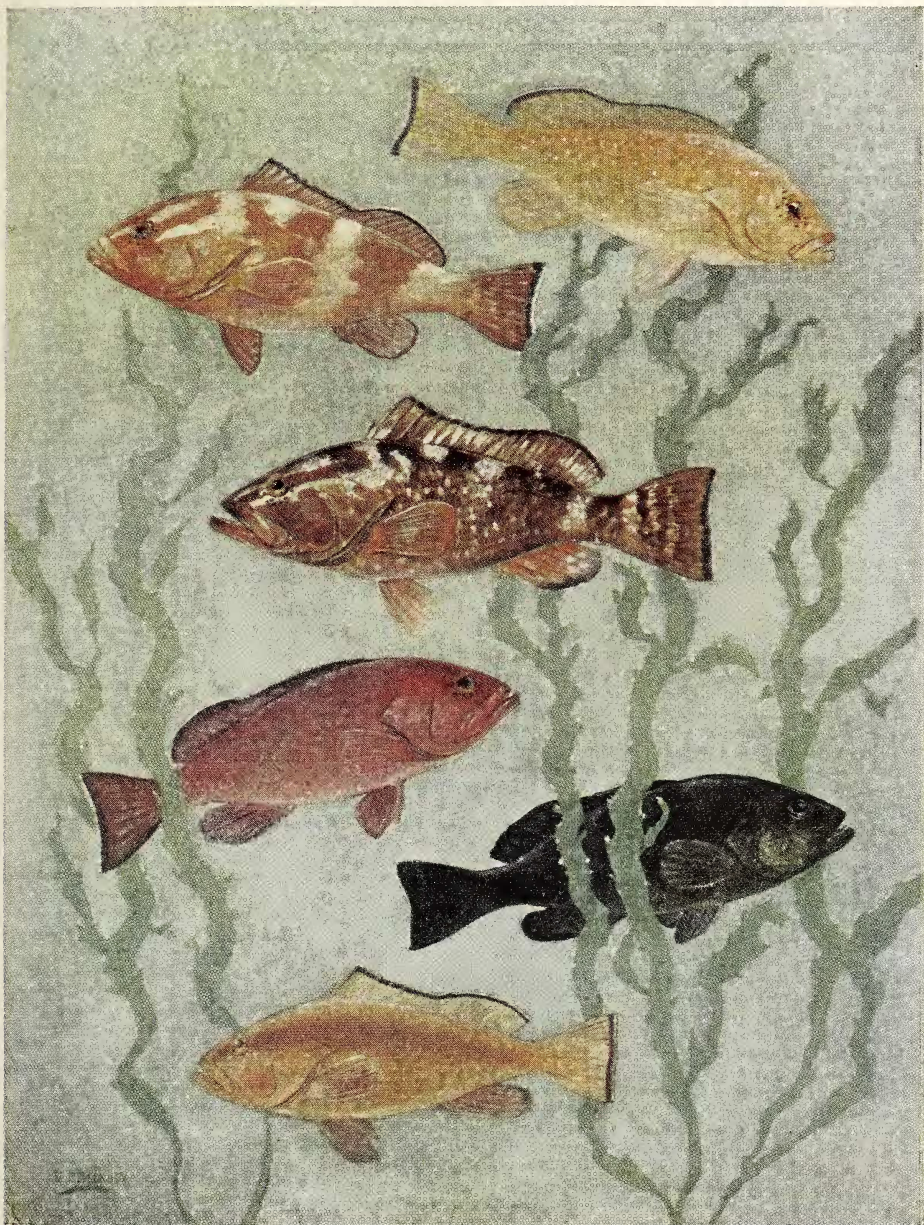


Plate 4. Red Grouper (*Epinephelus morio*). Six color changes.



Plate 5. Black Grouper (*Mycteroperca bonaci*). Four color changes.
See also photograph—p. 345

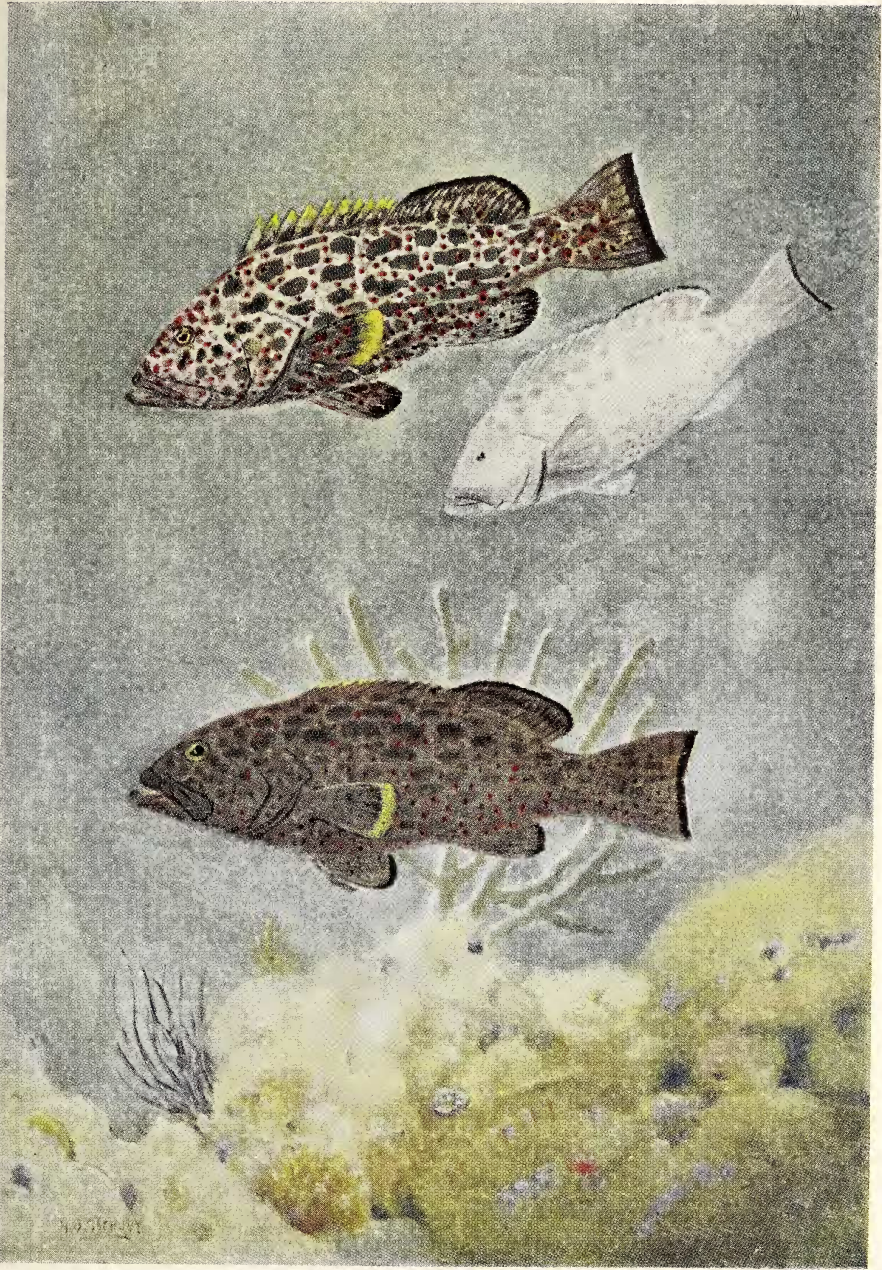


Plate 6. Yellow-finned Grouper (*Mycteroperca venenosa*). Three color changes. Deep water variety. See also plate VII, shallow water variety.



Plate 7. Yellow-finned Grouper or "Princess Rockfish." Three color changes (*Mycteroperca venenosa*). Shallow water variety. This plate supplemental to plate VI.



Plate 8. Giant Grouper (*Promicrops itiara*). Three color changes.



Plate 9. Coney (*Bodianus fulvus*). Five color phases.
See also photograph—p. 347



Plate 10. Graysby (*Petrometopon cruentatus*). Four color changes.

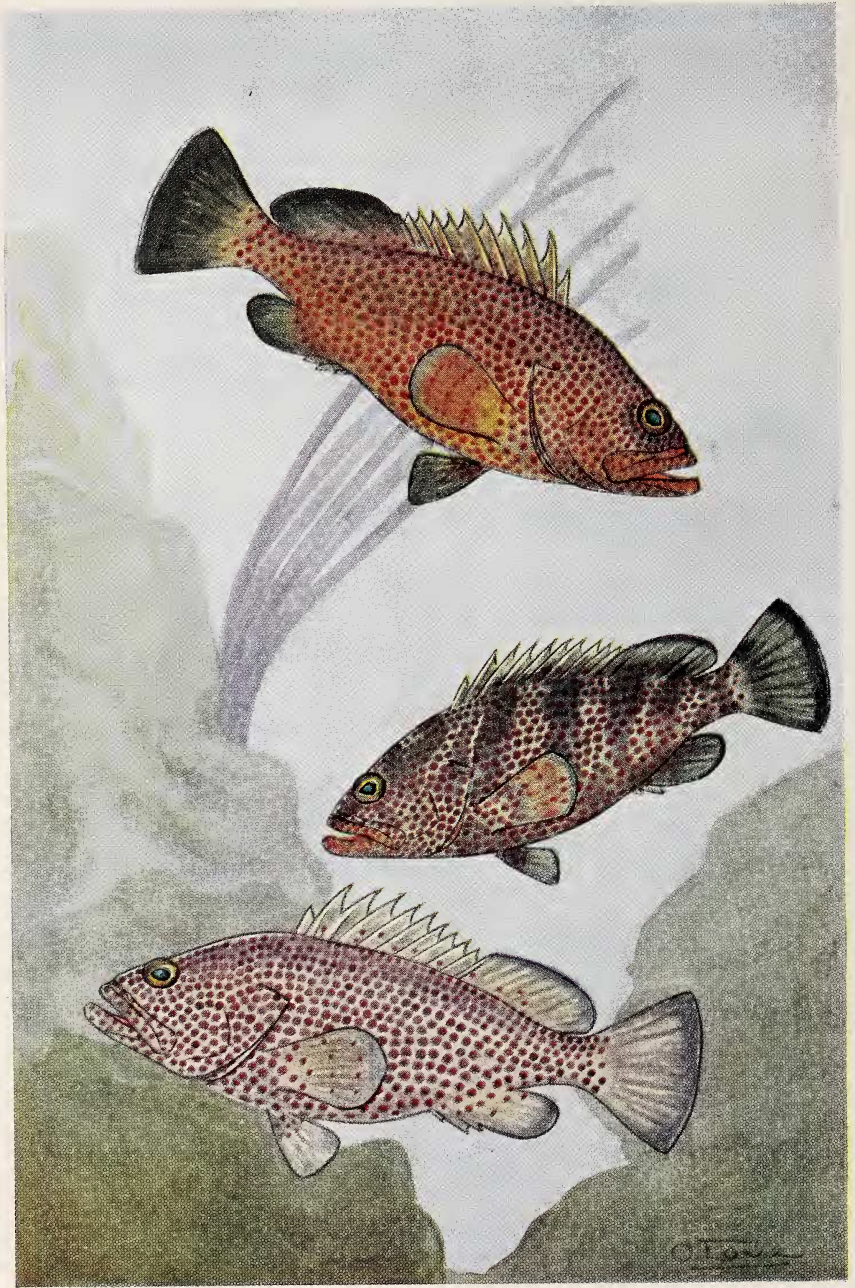


Plate 11. Red Hind (*Epinephelus maculosus*). Three color changes.



Plate 12. Rock Hind (*Epinephelus adscensionis*). Four color changes.



Plate 13. Blue-striped Grunt (*Haemulon sciurus*). Three color changes.



Plate 14. Gray Grunt (*Haemulon plumieri*). Three color changes.

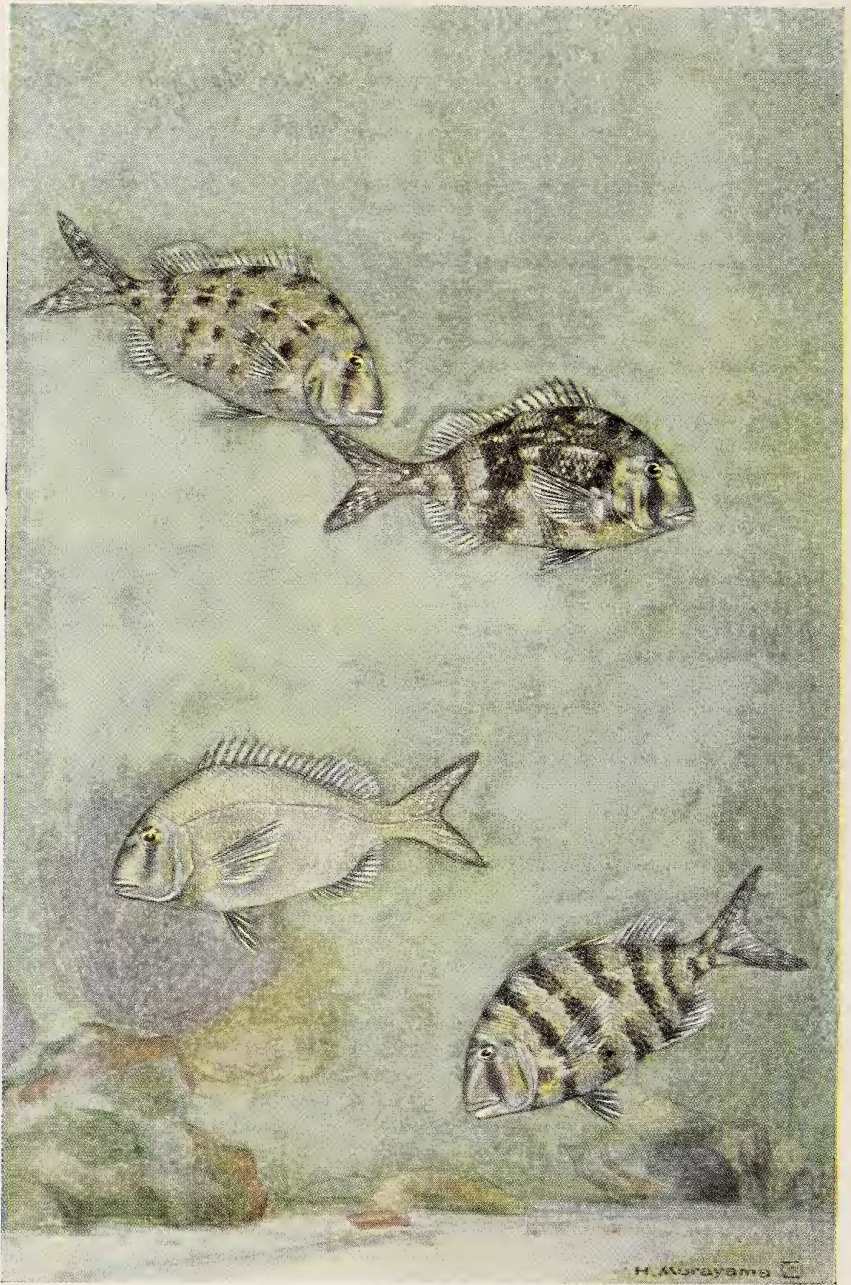


Plate 15. Grass Pogy (*Calamus arctifrons*). Four color changes.



Plate 16. Glass Eye (*Priacanthus arenatus*). Four color changes.



Plate 17. Sergeant Major (*Abudefduf saxatilis*). Three color changes.



Plate 18 Brown Parrot-fish (*Pseudoscarus guacamaia*). Three color changes.

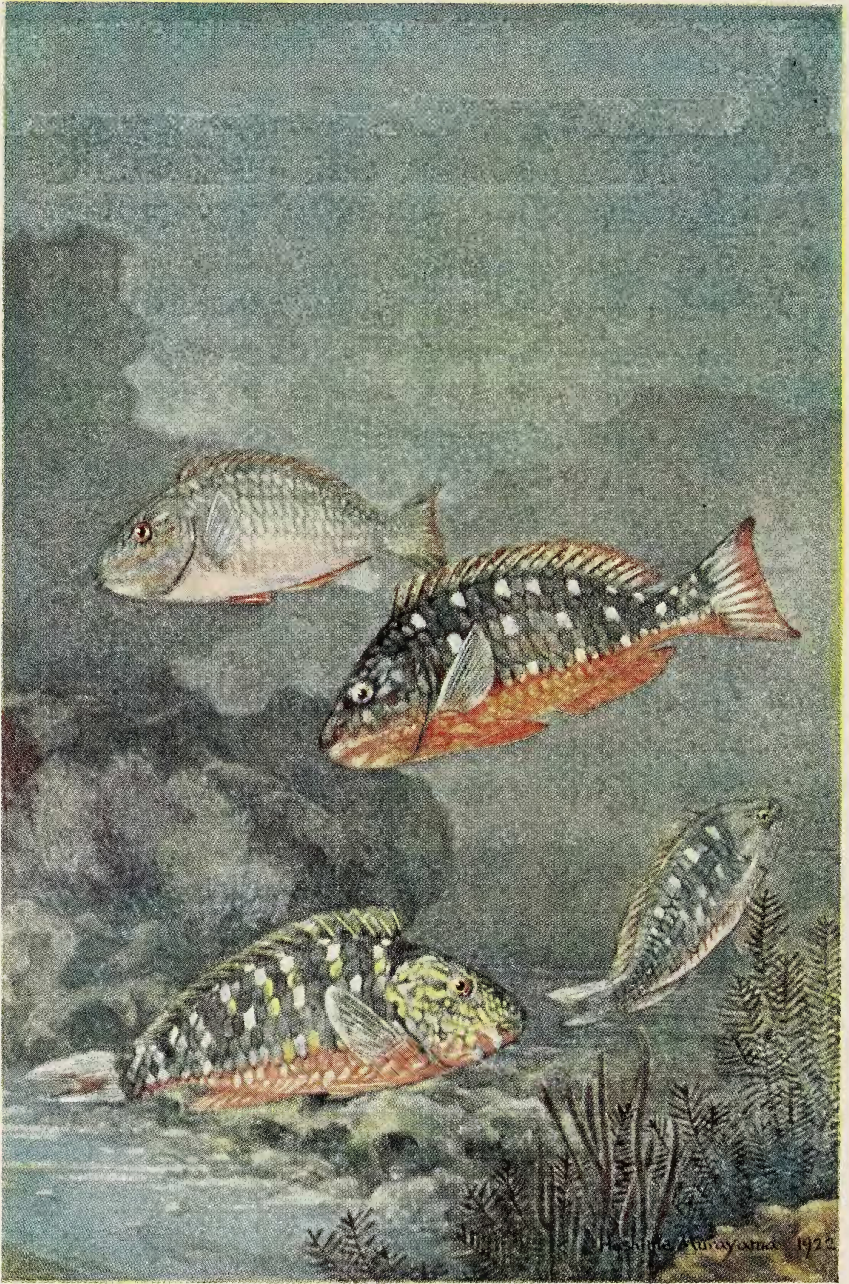


Plate 19. Red Parrot-fish (*Sparisoma abildgaardii*). Four color changes.
See also photographs on p. 349



Plate 20. Blue Parrot-fish (*Scarus caeruleus*). Four color changes.

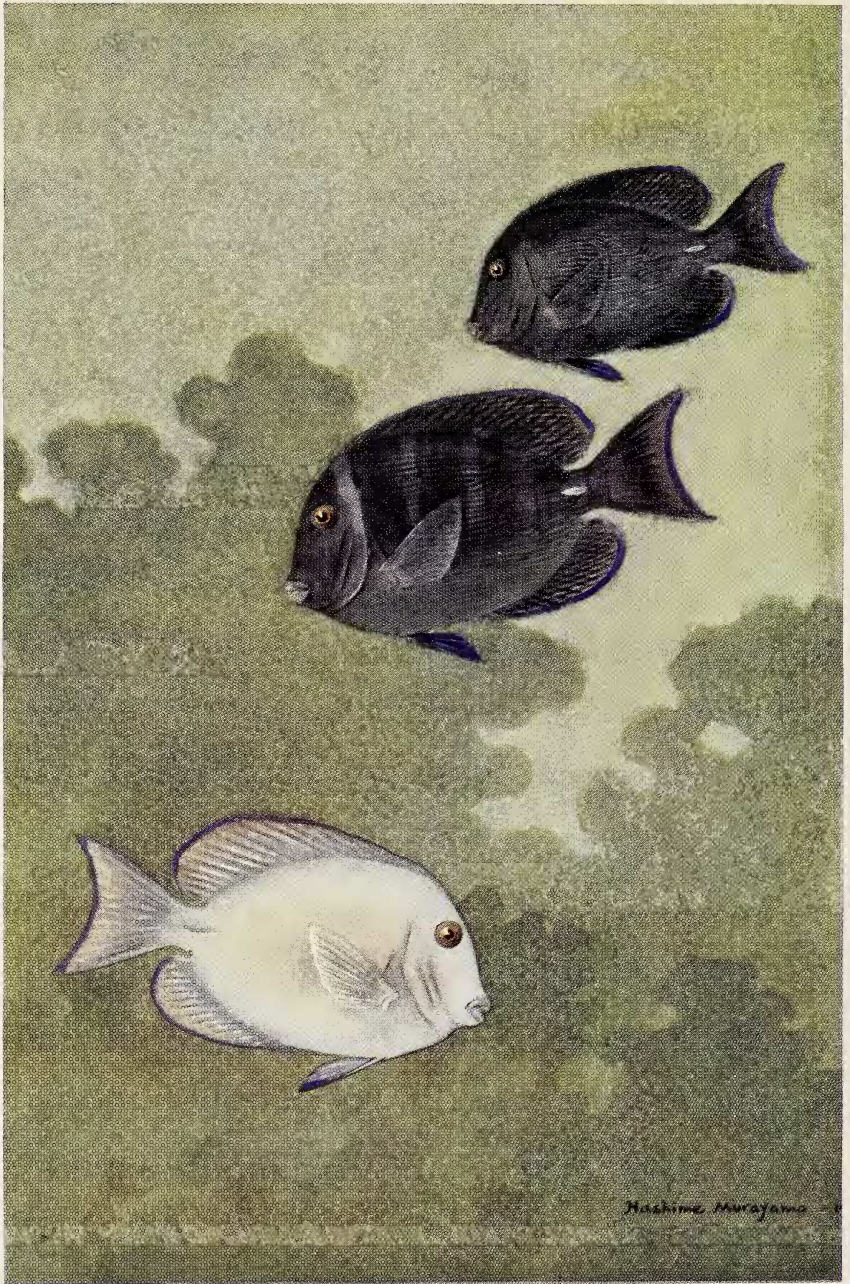


Plate 21. Blue Tang (*Teuthis caeruleus*). Three color changes.



Plate 22. Surgeon-fish (*Teuthis hepatus*). Three color changes.

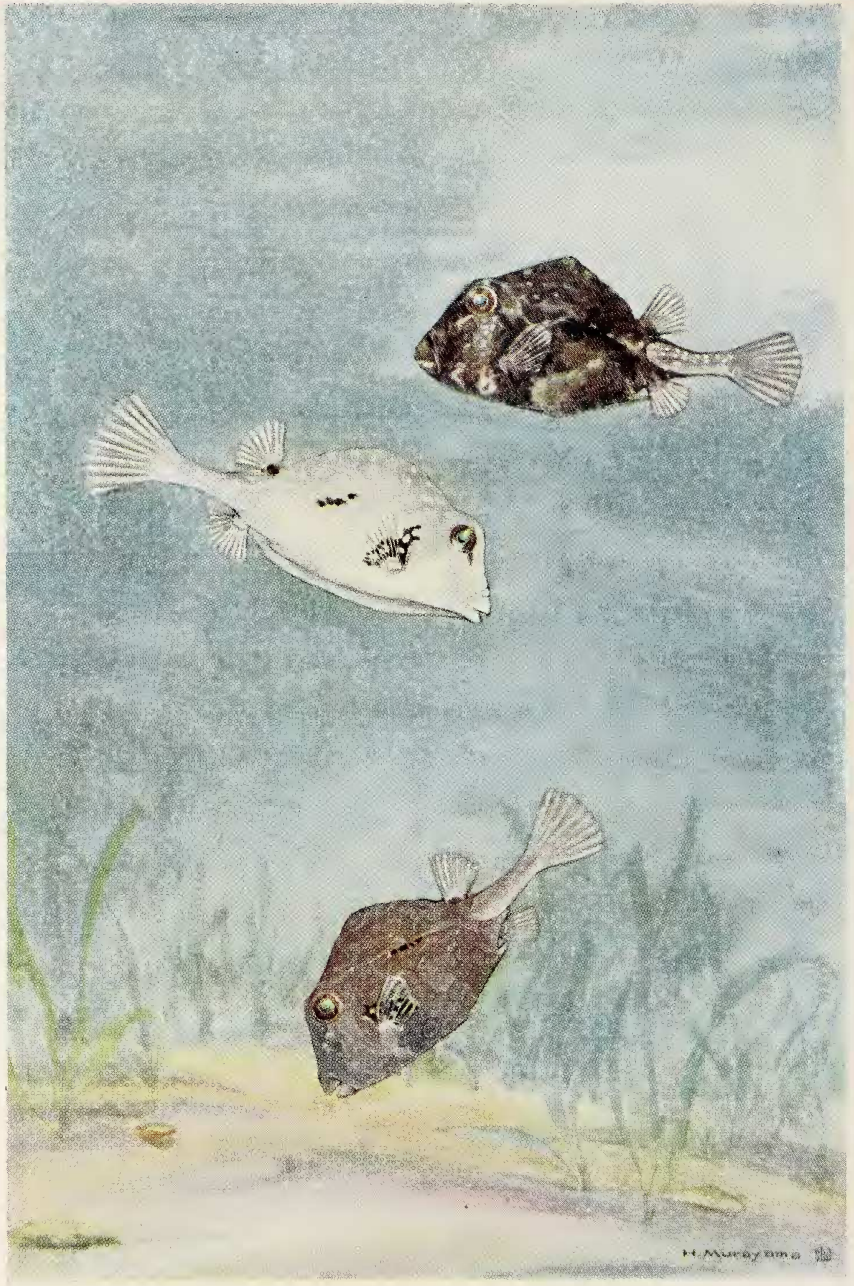


Plate 23. Buffalo Trunk-fish (*Lactophrys trigonus*). Three color changes.



Plate 24. Cowfish (*Lactophrys tricornis*). Four color changes.



Plate 25. Queen Trigger-fish (*Balistes vetula*). Four color changes.

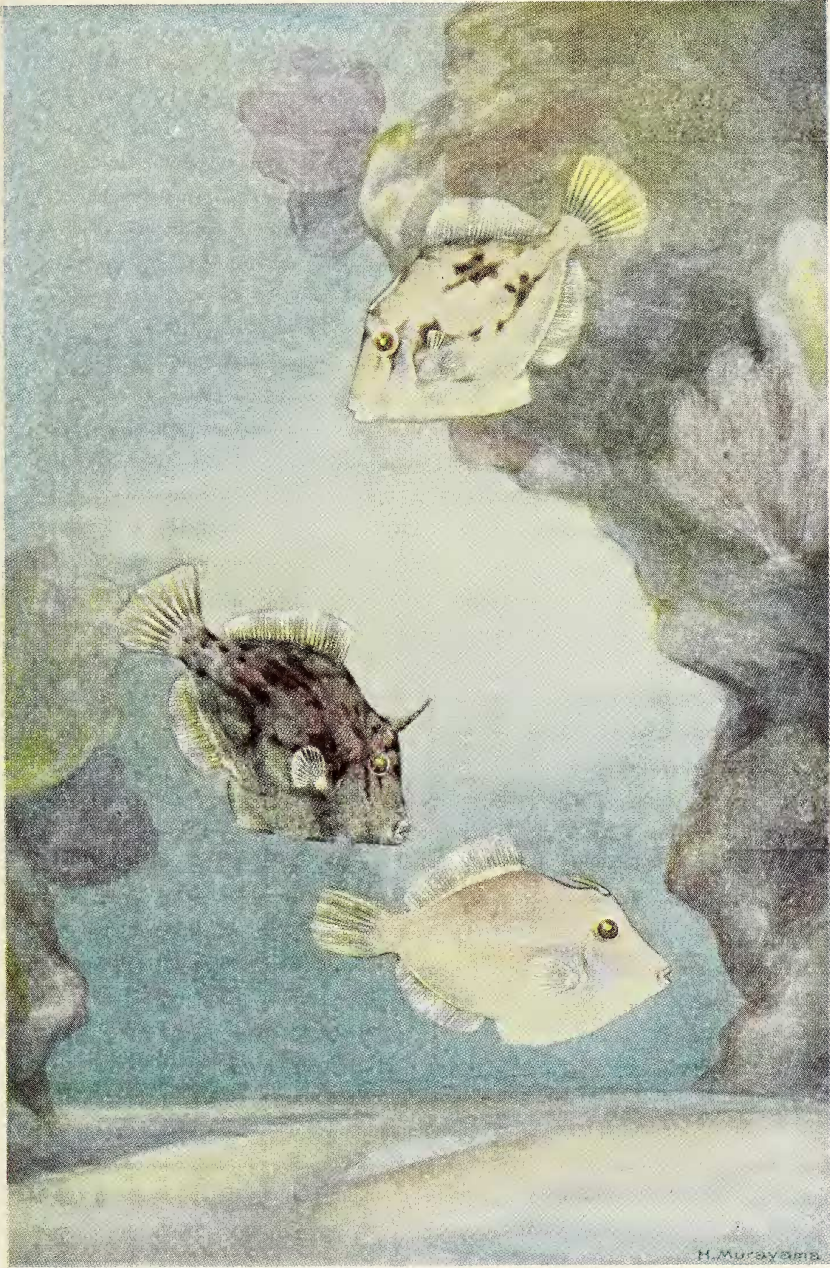


Plate 26. File-fish (*Mouacanthus hispidus*). Three color changes.



Plate 27. Hogfish (*Lachnolaimus maximus*). Three color changes.
See also photographs—p. 351